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Book review by Wayne P. Hughes Jr. of QED: The Strange Theory of Light and Matter by Richard P. Feynman and Physics Today, Volume 42, No. 2, February 1989, a special issue of articles about Richard Feynman and his work

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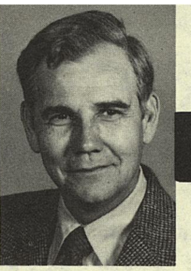

Edited By:

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Worth Reading

QED: The Strange Theory of Light and Matter

Richard P. Feynman
Princeton, New Jersey. Princeton University Press, 1985, 157 pp. and

Physics Today

Volume 42, No. 2, February 1989. A special issue of articles about Richard Feynman and his work.

Reviewed by ***Wayne Hughes, NPGS***

Everyone knows of **Richard Feynman's** effervescent book, *Surely You're Joking, Mr. Feynman,* a collection of anecdotes by one of science's supreme story tellers. If one is interested in how the physical world works as modern physics has deduced it, he can hardly do better than reading Feynman's *QED*, the acronym for quantum electrodynamics. There is also an operations analysis connection, which is how I came to read the book.

Mike Melich gave it to me. We had been talking about the nature of combat, and I had delivered my most extravagant lecture on the nature of military force, to wit, that it is not an analogy with the force of physics (F = ma, and all that), but that it was a real phenomenon, the effects of which were seen in every battle. Military men had not borrowed the term from physics, sez I, but the other way around. Force, of weapons, of politics, of literature, of theater, of money, was a concept among us human beings which physics coopted, defined with a model, and put to use to its own ends. Our force, the effects of combat, was far more complicated to describe and measure. It follows, I said, that if military men didn't stop regarding combat force as though we could measure it solely by its *Physical* effects in casualties and other destruction, we were never going to get very far in describing and understanding it.

I chose to work out the properties of combat force by defining (military) momentum, while Mike wanted to start with combat energy. Mike conjectured that a grounding in quantum theory was a good idea because to think through the complexities of the military problem one should know where physicists had been leading themselves. He was right to give me *QED,* even though "I've had all that stuff." Feynman is (a) current and (b) clear.

The current understanding of electrons and photons is quite remarkable. Quantum theory had succeeded in explaining everything only by retreating into probabilities, vectors, and mathematical models of exceeding complexity, the physical interpretation of which reduces physicists to an inarticulate mumble. They test the reliability and universal application ("truth") of their precise mathematical models by experiments based on the actions of one or a few particles, measured under exquisitely refined conditions. They believe that knowing how things (specifically electrons and photons) work one-on-one will be a reliable guide to how they work in the aggregate.

Enter Feynman, who had achieved and communicated much of this understanding to his peers, to explain it all in *QED* to us layman with both rigor and clarity, and I might add, plenty of diagrams, but with no mathematics except vector addition which he does for us graphically.

And ZAP!, on page 15 he confronts us with "I want to emphasize that light comes in this [discrete] form — particles. It is very important to know that light behaves like particles, especially for those who have gone to school, where you were probably told something about light [sometimes] behaving like waves. I'm telling you the way it does behave — like particles ...every instrument that has been designed to be sensitive enough to detect weak light has always ended up discovering the same thing: light is made of particles." No ambiguity with Feynman (barring the careful expression, "...light behaves like..."). All of the old vacillation we were taught about sometimes its particles and sometimes its waves is swept away.

It's true that later Feynman muses a little about inventing a better word, like "wavicles," but he's just setting us up to describe the totality of actions from which all phenomena of light and electrons arise:

> Action 1. A photon goes from place to place
> Action 2. An electron goes from place to place
> Action 3. An electron emits or absorbs a photon

By this time he has shown us how to compute the probabilities that any two particles will do action 1, 2, or 3 in time and space, and how the actions lead to anti-particles, and he is about to show us that to know the probability that one action will occur we have to compute the probabilities of all possible paths and interactions, according to rules which are simple to write (if you know what you're doing) and exceedingly intricate to apply, mathematically or in any other sense, except for the simplest and purest — the very cases physicists use to verify the quantum electrodynamic theory.

Feynman illustrates with clarity, beauty, and precision, that the aggregate phenomena we see in the world like the partial reflection of light from glass or the passage and "bending" of light through two apertures, are an enormous intertwining of tremendous numbers of photon exchanges and interferences. Knowing the rules ("laws" we say) for the three fundamental actions is only a very small beginning toward analyzing real situations. There are so many photon interchanges going on that it's impossible to calculate them. "So we in-

vent such ideas as 'index of refraction' or 'compressibility' or 'valence' to help calculate in an approximate way when there's an enormous amount of detail going on underneath." As he says, the rules of chess are simple; playing chess well is difficult.

This is a book that takes all of Feynman's talents as a skilled communicator. It ought to be read by military analysts and philosophers and theologians partly because we all ought to know how things in the physical world work but also because it shows how physicists have been reduced to explaining it — even someone as remarkable as Feynman. In one sense *QED* is a source of joy because it unifies and explains many mysteries. But in another sense it only adds mystery and awe. *QED* explains everything, to quote Feynman, about electrons, photons, and chemistry. But to Einstein's everlasting disappointment, the explanation involves probabilities, chance, and irreducible residual uncertainty. The explanation and computations become so involved for simple events that when more complicated interactions enter, the "real" explanation recedes into the background, and we are driven to simpler models like that for the index of refraction. The real explanation becomes an oracle behind a curtain. It is like a great distant star which may be consulted to be sure we are on the right path to knowledge of matter and energy, but which itself cannot be reached. It "explains" — is the source of truth about every phenomenon of photons and electrons — but cannot be used to do the calculations of very complicated interactions. We must shift from a micro model to a course grained macro model and surrender precision and predictive power. We have a faithful mathematical model which we cannot use on the most powerful computer because the computations are too involved. We have to streamline the calculations, with quantum electrodynamics giving confidence that the streamlined version is about right.

Where does that lead us military analysts? Well, to humility for certain. Also, to be more demanding about our ability to describe combat and less demanding about our ability to predict results. Physical things can be described completely as interchangeable energy and matter obeying fixed rules. It has been suggested that living things can be described completely as bundles of interchangeable energy, matter, and communicated information (skills and knowledge communicated by genes and grunts). If human living things are a higher order, then we probably incorporate something else. How about interchangeable energy, matter, information, and instructions?

Don't press me: I'm no Richard Feynman, neither as scientist nor teacher. But the study of command and control needs help, and "instructions" sound to me like the communication of orders, wishes and desires, which are transformed into actions which become combat force. It would be nifty if we had some theory which would describe the creation of combat force, so that we could conduct some little (but not simple) experiments at the micro level.

There is another approach to Feynman, if you are more interested in the man and his accomplishments, as described by his friends and peers. *Physics Today* has given over its entire February 1989 issue to articles about him and what he did and how he earned his Noble prize. He was quite a guy. ▣

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AORS XXIX

The Twenty-ninth Annual US Army Operations Research Symposium (AORS XXIX) will be held 10 and 11 October 1990, at Fort Lee, Virginia, for some 300 invited government, academic and industrial leaders.

The theme is "Analysis — Meeting Changing Requirements and New Challenges." The symposium will allow an exchange of information and experiences on significant Army analyses, ongoing or completed recently, to enhance Army analysis, expose the practitioners to constructive critique, and the perspective of the analysis community.

Papers will be solicited which address the theme of the symposium, and selected papers and presentations will be published in the proceedings. The US Army Materiel Systems Analysis Activity (AMSAA), directed by Mr. **Keith A. Myers**, is responsible for the overall planning and conduct of AORS XXIX. For the seventeenth consecutive year, the US Army Logistics Center and Fort Lee, commanded by LTG **Leon E. Salomon**, and the US Army Logistics Management College, commanded by COL **David L. Asbury**, will serve as co-hosts.

For details, contact **Glenna Tingle**, (301) 278-6576, Autovon 298-6576, or **Margie Stidman**, (301) 278-3398, Autovon 298-3398. ▣